CHAPTER 1

Overview of Microbial Hazards in Fresh Fruit and Vegetables Operations

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1.1 INTRODUCTION

Scientists recommend that everyone eat five to nine servings of fruit and vegetables every day in order to promote good health. The improved availability of fresh produce year round and increased choices of items on the supermarket shelves should certainly help consumers to meet this target of fresh produce consumption. Raw fruit and vegetables, however, have the potential of becoming contaminated with microorganisms, including human pathogens. Several widely publicized foodborne outbreaks in recent years have been associated with sprouted seeds, minimally processed produce, unpasteurized vegetable and fruit juices, as well as intact products. However, the proportion of fresh-produce-related outbreaks is low when compared to the number of foodborne outbreaks per year.

Fruits and vegetables normally carry nonpathogenic, epiphytic microflora. During production on the farm and all stages of product handling from harvest to point of sale, produce may be contaminated with pathogens (Beuchat, 1996; Beuchat and Ryu, 1997). Possible microbial hazards on the farm include the use of raw manure and contaminated soil amendments, dirty irrigation water, wild animals and birds, and dirty farming equipment. At harvest, employee health and hygiene is critical. In addition, farm tools, utensils, and packaging could possibly contaminate the product. Packhouses pose a risk when using water to wash product or convey product in water flumes. The water quality plays a key role in determining the final quality and safety of the product. Employee hygiene and food contact surfaces have the potential to affect product in the packhouse. In addition, transportation and distribution practices determine product quality and safety for future use. When product is displayed at retail and handled in food service operations, there is the potential for contamination. The end user or consumer also plays a critical role in maintaining product safety as produce items are taken from the store, preserved, and prepared in the home.

Major stakeholders in the fresh produce chain have introduced measures to prevent product contamination (FDA/CFSAN, 2001a). At the farm level, Good Agricultural Practices (GAPs) and documentation of these practices were introduced. Government guidelines for the industry help in promoting safe practices and large retailers encourage the use of these guidelines by demanding results of audits of practices (FDA, 1998a, b). Retailers feel assured that the product presented to consumers has been handled safely when farms and packhouses are audited to guidelines and standards.

Minimal processing of fruits and vegetables presents unique challenges, because cutting and slicing remove the natural protective barriers of the intact plant. Thus, implementing Hazard Analysis and Critical Control Points (HACCP) programs in high care facilities adds more assurance of food safety. More research is needed in the fresh produce chain to prove the effectiveness of mitigation measures. Many monitoring programs are based on assumptions that contamination can occur. Scientists have used surrogate organisms to imitate the survival of microbial pathogens in fresh produce and these studies could provide significant insight into controlling the spread of pathogens in the industry (FDA/CFSAN, 2001b).
Produce is moved globally to supply year-round demands and improvement in traceability methods would help in epidemiological investigations. Outbreak data have been limited to just a few industrialized nations because only these countries have active surveillance systems for monitoring. Thus, the generation of more epidemiological data on produce-related foodborne illness worldwide will help determine true levels of illness.

1.2 PATHOGENS AND OUTBREAKS ASSOCIATED WITH THE FRESH PRODUCE INDUSTRY

Biological hazards are of great concern to the fresh produce industry. They can be classified into spore-forming bacteria, non-spore-forming bacteria, viruses, and parasites. Certain bacteria form spores to withstand environmental stress conditions such as high heat on freezing. Spore-forming organisms can attach to vegetables grown near the soil. Examples of these organisms include Bacillus cereus, Clostridium perfringens, and Clostridium botulinum. Maintaining refrigeration temperatures at less than 5°C and promoting oxygen in packaging would reduce the risk of vegetative cell formation and the production of dangerous toxins that cause illness (Linton, 2003). Non-spore-forming bacteria such as enterotoxigenic and enterohemorrhagic Escherichia coli, Campylobacter jejuni, Listeria monocytogenes, Salmonella, Shigella spp., Staphylococcus aureus, and Vibrio spp. could contaminate fresh produce by cross contact with humans or animals carrying these organisms. The fecal–oral route is possibly the main mechanism of transfer. All of these bacteria have been associated with publicized fresh produce foodborne outbreaks of public health significance. The transfer of these organisms could be controlled by practising good personal hygiene, cleaning food contact surfaces, and always using potable water when water is required.

Foodborne viruses require a living host in which to grow and reproduce. Viruses tend to move from one food to another, from water supply to food, or from food handler to food. Hepatitis A, Norwalk virus, and rotavirus are viruses of public health significance. Hepatitis A has been isolated in vegetables washed with nonpotable water. A food worker can carry the organism virus for up to six weeks and contaminate food and other workers without any knowledge of signs and symptoms. The Norwalk virus and rotavirus have been associated with many foodborne infections. Raw fruits and vegetables washed with contaminated water were implicated in some outbreaks. These viruses are transmitted by person-to-person contact and by fecal contamination. Practising good personal hygiene and controlling staff carrying the virus are measures that could possibly eliminate foodborne illness.

Parasitic protozoa include Cyclospora cayetanensis, Giardia lamblia, and Cryptosporidium parvum. They are single-cell microorganisms that must live on or inside a host to survive. These parasites may be transmitted via contaminated water, by person-to-person contact, and by fecal contamination. Use of potable water for operations is critical.
In the last 15 years, knowledge of foodborne disease epidemiology evolved while the fresh fruit and vegetable industry was undergoing notable changes. Factors increasing the risk of foodborne illness associated with fresh produce include the following:

1. Modifications in agronomic practices, processing and packaging technologies;
2. Global marketing strategies allowing fresh produce supply to consumers with a wide variety of products, year round;
3. Changes in population demographics; and
4. Changes in food consumption patterns.

Increased awareness because of unique epidemiologic surveillance programs and increased media attention has contributed to better documentation of foodborne illness. Numerous pathogens have been isolated from a wide variety of fresh fruits and vegetables. It is important to note that the number of samples in each study varied substantially. Although not all of the pathogens have been associated with produce-related foodborne disease outbreaks, they are all capable of causing illness.

In the United States, a specific etiologic agent was identified for 187 produce-associated outbreaks during the years 1990–2002. Among these outbreaks, 102 (55%) were caused by bacteria, 68 (36%) were caused by viruses, and 17 (1%) were caused by parasites. Among the bacterial agents, *Salmonella* accounted for 60% of outbreaks, and pathogenic *E. coli* was responsible for 25% of bacterial outbreaks. Norovirus caused a majority of viral outbreaks, accounting for over 80% of cases. The apparent prevalence of norovirus has increased possibly as a result of improved surveillance and detection methods. *Cyclospora* caused the majority (65%) of parasitic produce-associated outbreaks. Over 40% of the outbreaks were caused by salad items (including lettuce and tomatoes), whereas fruit and fruit salads comprised 13% of the outbreaks. Melons, including cantaloupe, honeydew, and watermelon, represented 12% of produce-associated outbreaks, and sprouts comprised 10% of the outbreaks (CDC, 2004).

In spring of 1996, CDC and Health Canada were alerted to over 1465 cases of foodborne illness caused by *Cyclospora* in the United States and Canada. The source of illness was incorrectly identified as California strawberries. At the peak of the California strawberry season, this mistake cost the industry $16 million in lost revenue (Calvin et al., 2002). It was later discovered that the illness was caused by Guatemalan raspberries and the United States stopped all imports of this commodity. Another incident occurred when 200 school children and teachers in Michigan contracted Hepatitis A in 1997. This outbreak was traced to frozen California strawberries. The fresh strawberry industry, through the California Strawberry Commission, was quick to alert the public of the subtle difference with the fresh strawberry market, thus limiting the financial impact and decline of fresh market sales as in the previous year (Calvin, 2003). Japan had the world’s largest reported vegetable outbreak in 1996 when over 11,000 people were affected and 6000 were culture confirmed. Three school children died from this outbreak,
which was caused by *E. coli* O157:H7 (Ministry of Health and Welfare of Japan, 1997). In the United States, *Salmonella* traced back to Mexican cantaloupes caused outbreaks in 2000, 2001, and 2002. The investigation was time-consuming and caused a decline in California cantaloupe sales following the Mexican growing season.

Growers and shippers were the focus of U.S. government investigations in the mid-1990s for outbreaks of food illness linked to fresh produce (Tauxe, 1997). Epidemiology of foodborne outbreaks will be discussed extensively in a following chapter. The lack of strong traceability details and poor reporting systems for outbreaks limits a thorough evaluation of the role of fruits and vegetables as a source of foodborne infections (European Commission, 2002).

### 1.3 POTENTIAL HAZARDS IN THE FOOD CHAIN/POINTS OF CONTAMINATION

#### 1.3.1 Hazards in Production

*Ranch History and Adjacent Land Use.* The ground where product is grown plays a vital role in safety of the product. If the area has a history of use for chemical waste or the processing of biosolids, this would present a potential source of contamination for crops. It is important to know the land history and the time required for the area to lay fodder, thus reducing the level of contaminants in the soil. Adjacent land use also affects the safety of the crop grown. If fruit and vegetables are grown next to an animal-rearing operation, there is a potential for product to become contaminated by animals. These animals may physically enter fields. Waste, high winds, and run-off from the animal operation may contaminate crops. The decision to grow next to a potentially hazardous location should be followed up with a risk assessment and the implementation of preventive measures to control risks identified. Sloping land from an adjacent field could be curbed by digging a ditch along the full length of the field to catch run-off water. Physical barriers and trenches may also prevent unwanted animal entry into fresh produce operations.

The importance of adjacent land was demonstrated in the first documented outbreak of *Escherichia coli* O157:H7 infection associated with a treated municipal water supply in Canada in May–June 2000. This was the largest multibacterial waterborne outbreak in Canada at that time (Public Health Agency Canada, 2000). The Walkerton residents who became ill numbered approximately 1286. Researchers confirmed that a well was subject to surface water contamination and elevated turbidity. Environmental testing of 13 livestock farms within a 4 km radius of the three wells identified human bacterial pathogens in animal manure on all but two farms. On nine farms, *Campylobacter* spp. were identified, on two farms both *E. coli* O157:H7 and *Campylobacter* spp. were found; this included a farm adjacent to the affected well. The evidence suggested that the pathogens that entered the well were likely to have originated from cattle manure on this farm (Public Health Agency Canada, 2000).
**Animals.** Fruit and vegetable growers and packers are discouraged from keeping animals because they represent a source of product contamination. Domestic animals such as chickens, dogs, and horses can contaminate crop with fecal droppings if they pass through growing areas. Nonfarm animals such as deer, other mammals, and birds can serve as reservoirs for pathogens (Dingman, 2000; Moncrief and Bloom, 2005). Wild animals present a unique hazard to fruit and vegetable growers and these animals are difficult to control. Droppings from birds, deer, and other wild animals present a risk. It is not economical in some instances to fence large production areas, but small farms may be fenced to keep out wild animals. Other physical barriers such as mounds, diversion berms, vegetative buffers, and ditches, provide protection from animals. Growers use scarecrows, reflective strips, and gunshots to ward off birds and pests from crop. Mechanical traps have been used to catch fieldmice in lettuce-growing operations in Yuma, Arizona. Growers implemented this emergency measure to alleviate a problem of mice in lettuce bound for the prepared salad industry. This measure was simple, yet effective in preserving product integrity.

**Manure and Soil Amendments.** An increased demand for organically grown produce promotes the use of alternative measures to protect plants from pests, mites, and fungi. In addition, organic fertilizers such as animal manure could introduce fecal pathogens to fresh produce if manure is not aged and treated before application. Treated manure or biosolids can be beneficial soil amendments. Growers have to manage these amendments very well to minimize contamination of fruits and vegetable with pathogenic fecal microorganisms. Published literature shows the presence and isolation of zoonotic pathogens in manure and on the surface of fresh produce (Dingman, 2000; Moncrief and Bloom, 2005). However, more research is needed to show a direct link from a manure application to finding pathogens in fresh produce. This research could help in assessing the level of risk. Active composting uses three Ts to treat manure: time, temperature, and turnings.

Composting can effectively reduce pathogens and parasites commonly found in manure as well as those that have mutated into different strains with new abilities, like surviving in acidic environments. Millner (2003) estimates that once certain time and temperature criteria are achieved, *E. coli* and *Salmonellae* in the compost are nearly eliminated (99.9999 percent kill rate). The pathogen-reduction criteria include a temperature of at least 131°F for three consecutive days in an aerated pile or 131°F for two weeks in the hot zones of a windrow pile with five turnings. This process can kill nearly all pathogenic microbes and still maintain populations of beneficial ones.

Applying raw manure to a vegetable-growing operation could cause product contamination. In addition, manure piles stored next to growing operations may also be a problem because of run off. Organic growers use a great deal of treated manure as fertilizer and soil amendment. Organic growers must be vigilant not to use fresh manure, because this would increase the potential for product contamination (Blaine and Powell, 2004; FDA, 1998b). Manure application should be carried
out well in advance of harvest so there is sufficient time for potential pathogens to break down naturally.

**Water.** Water may be used throughout the growing and harvesting of fresh fruit and vegetables. Irrigation water and water used for application of plant protection product, fertilizer, and frost protection should not introduce risk of pathogens to product. The source of agricultural water could determine the final safety of the food product. Municipal water or wells are generally safe. In the United States, municipal water is usually treated and tested routinely to monitor microbial contamination. Wells with sound casing and absence of leaks should provide water free of pathogens. Many growers also draw water from open water systems in areas where water is scarce. If effluent water from sewage plants is used in hydroponics plant production, the quality of this water is a concern for introduction of pathogens in edible food. The microflora of these systems changes daily and it is unknown what quality of water exists from one day to the next. Irrigation practices dictate product safety when using open systems like rivers and canals. Drip irrigation or furrow irrigation would bring water to the root of the plant without making contact with leaves or other edible portions. In the early growing stages, it is possible to use sprinklers to wet young plants. The time interval between planting and harvesting is sufficiently long to expect pathogens present to die off.

Greenhouse production is generally well protected from the environment, but is seen to favor the survival of human pathogens (Nguyen-the and Carlin, 2000). Special issues of control of pathogens in greenhouses concern the fact that all nutrients are delivered to plants in liquid form. If water used for mixing agricultural chemicals becomes contaminated in any way, the implications for the greenhouse are extensive. The pathogen would spread over a wide range of product on which it was applied. The conditions in the greenhouse – warm temperature (>21°C), moisture (>70 percent relative humidity), and light – would encourage the growth of pathogens (Moncrief and Bloom, 2005).

### 1.3.2 Contamination in the Field at Harvest

Harvesting is a critical period in the fresh produce chain, with potential for most product contamination. Employees in farming operations play a key role in maintaining the integrity of product grown. Their safe and hygienic practices – from land preparation, planting, weeding, and pruning, to harvesting – could influence whether product becomes contaminated. Personal hygiene, including hand washing all along the food chain, is critical in reducing or eliminating contamination with fecal pathogens. Ill employees harvesting by hand could contaminate product bound for the consumer if care is not taken in basic hygiene. Growers may use portable toilet facilities that follow workers in large fields to provide sanitary facilities. As part of Good Agricultural Practices (GAPs), companies train field employees in the basics of using toilet facilities instead of the field, where product may be contaminated. Employees are trained in proper hand-washing techniques. In the United States, the Occupational Health and Safety Act (29) CFR 1928.110,
subpart I, regulates the use of portable toilets. The Act specifies that the following practices should be adopted:

1. One toilet should be provided for every 20 workers.
2. The field sanitation unit should be placed within one quarter mile of the harvest crew.
3. Sanitary tissue, and soap and potable water for hand washing should be provided.
4. A means of hand drying, preferably disposable paper towels, should be provided.
5. Sanitary facilities in the field must be managed effectively so they do not become a source of contaminated product. A professional company should be used to empty and clean sanitary facilities.
6. Growers should have a containment plan in place in the unlikely event of a spillage.

Wounds are hosts to pathogenic bacteria and direct food contact should be avoided. Workers who receive minor cuts while harvesting should only continue to work if the cut is well protected using a plaster/bandage, and further covered with gloves. If gloves are used, they should not cause product contamination. Thus, gloves should be changed regularly or when damaged.

Equipment used for harvesting may also be a source of product contamination. Utensils should be cleaned and sanitized regularly to avoid cross-contamination. Some growers now use a sanitizing dip in the field during harvest so knives and other tools can be cleaned during the break and before start of harvest. Field containers should be washed routinely to avoid a build-up of debris. Some packhouses are equipped with crate washers that comprise a tunnel full of powerful water jets and in some cases an initial spray of foam cleaning detergent. Because produce crates are taken to the field daily, it is important not to create any instance of cross-contamination of produce by using dirty packaging.

Minimal processing of produce items like romaine hearts and head lettuce may be carried out in the field. Product is harvested, rinsed in the field on harvest rigs, and then packed in consumer packages and boxes. The harvest rigs should be cleaned and sanitized daily, because these products are advertised as “ready-to-eat”. Any wash water used on harvest rigs should be potable and suitable for its application. Utensils and vehicles used to transport packaged fruit and vegetables should be dedicated for this purpose, because cross-contamination could occur if other products are transported in the same vessels. A precautionary measure would be to wash and sanitize containers before use.

1.3.3 Post-Harvest Handling of Fresh Produce

Packhouses. After product is harvested, it should be protected to prevent any cross-contamination. Packing facilities should be cleaned and well maintained to
reduce the introduction of harmful microorganisms to product. Some growers move product from the field in large bins, which are taken to the packhouse for selection, grading, and repacking. No matter what method of packing is used, care must be taken with product. Cartons and other empty containers should not be stored uncovered in fields, because dust and animals could contaminate product. Rigs and utensils used for packing should be cleaned and monitored daily. Packhouses, whether open or enclosed, should be cleaned and protected to deter pest entry and possible product contamination. Harvest storage facilities, containers, or bins should be cleaned regularly, based on a set program.

Poor sanitation in the packhouse could lead to the formation of biofilms. Biofilms are layers of bacteria that attach to surfaces like stainless steel and plastic, and also attach to each other with the help of polymeric materials. The biofilms trap other bacteria, debris and nutrients. Poor sanitation programs cause biofilms to build up and become established. Nonpathogenic and pathogenic bacteria can form biofilms. Organisms in the film tend to be resistant to cleaners and sanitizers, as well as heat treatment. Thus, in the food industry a sound sanitation program is needed so that biofilms do not become entrenched on food contact surfaces.

Good sanitation practices enhance a company’s food-safety program. An important step is to provide training in sanitation to a wide base of employees, even those outside the sanitation department (Redemann, 2005). In daily sanitation programs, seven steps could be followed to ensure clean equipment:

1. Dry cleaning to remove gross debris from equipment and floors;
2. Prerinsing to remove debris from surfaces;
3. Using soap and scrubbing equipment on surfaces and floors;
4. Postrinsing to remove soap;
5. Removing standing water and reassembling equipment if necessary;
6. Inspecting cleaned area and recleaning with detergent if necessary;
7. Sanitizing equipment and floors in high-care facilities.

Many companies use chlorine-based cleaning chemicals. For effective cleaning, some chemicals could require a specific residence time on equipment. Sanitizers include halogen-based compounds and quaternary ammonium-based compounds. For a review on food plant cleaning and sanitizing, the reader is referred to Redemann (2005).

Pest management could prevent product contamination, recall, and other loss of productivity. A company should have a preventive program of pest control so that problems never develop. The packhouse manager should assess the risk in the plant to determine the level of prevention needed. Completely closed packhouses may have sophisticated pest control programs using a certified contract company. Windows and air vents should be screened and facilities kept free of debris. Any pest-control program implemented should be monitored and documented regularly to protect product.

**Water Flumes.** Where water is used to transport produce from one part of the packhouse to the next, the quality of that water will determine the quality and
safety of the product being packed. Primary water for rinsing to remove dirt may be of agricultural grade. However, potable water should be used for subsequent rinsing steps. Fresh-cut rinsing operations may use automated chlorination and acidification systems to control and monitor water quality. Flume channels used for sorting and grading product should be cleaned according to a planned sanitation program, thus preventing the build-up of debris from recycled water and avoiding product contamination. Where water is recycled, it should be treated to reduce the build up of microorganisms. Many companies use chlorine or other disinfecting chemicals to control the microbial load. Packers and processors use chlorine dioxide, chlorine (hypochlorous acid), UV light, ozone, hydrogen peroxide, peroxyacetic acid, and other sanitizers. The standard sanitizer used in packhouses in the United States is chlorine. This could be in the form of sodium hypochlorite granules, tablets, or liquid.

Water has been demonstrated to enter tomatoes through the stem end in a water dunk tank. This may be caused by the temperature differential of the produce item harvested in the field and the cooler water in the packhouse. At intake, any microorganisms in the water would also enter the produce item. Thus, it is imperative that any wash water in the plant be potable water. Any pathogens in water could become the source of a foodborne outbreak. A multi-State outbreak of *Salmonella enterica* Serotype Newport infection was linked to mango consumption in December 1999. Traceback of the implicated mangoes led to a single Brazilian farm, where hot water treatment was identified as a possible point of contamination. Hot water treatment was a new process introduced to prevent importation of an agricultural pest, the Mediterranean fruit fly. Contaminated water caused product contamination. This outbreak highlighted the potential global health impact of foodborne diseases and newly implemented food processes and the vulnerability of product placed in contaminated water (Sivapalasingam et al., 2003).

**Employees.** Packhouse employees should be trained in safe food-handling practices. Product safety of final consumer packs is directly influenced by the handling practices in the packhouse. Employees should receive training on the proper use of toilets, hand-washing procedures, use of protective clothing, and headgear to avoid product contamination. Many foodborne outbreaks have been linked to a sick employee who transferred pathogens via the fecal–oral route. Employees shedding pathogens in diarrhea may not wash their hands adequately before handling food. This is one possible route of contamination of fresh produce.

### 1.3.4 Storage and Distribution

Refrigeration temperatures in storage and distribution are crucial to maintaining product quality. These temperatures also reduce the proliferation of human pathogens if they are present on produce items. Refrigeration units are thought to spread mold throughout warehouses, and routine servicing of air filters and
refrigeration systems is required. As cold air systems blow mold spores into the air, there is also the risk that pathogens may be spread along with the spores from one pallet to the other. More research is needed in the area of air quality in storage and distribution in order to implement effective control measures. This topic will be discussed extensively in Chapter 7.

Pest control programs are necessary at any storage facility. A basic rodent control program would reduce the presence of pests that harbor harmful microorganisms forming a potential hazard to food. A contract company or trained individual should monitor traps or bait stations regularly and document any pest activity observed.

Vehicles and containers used to transport fresh produce could also be sources of potential contamination. Vehicles used to transport fresh produce should be clean and free of odors, dirt, and debris before loading. The ideal situation would be to use dedicated containers and vehicles for each application; that is, produce, meat, or refuse should be transported by separate means. The produce containers and vehicles should also be cleaned routinely as part of Good Hygienic Practices (GHPs) to prevent contamination between loads. Good hygienic and cleaning practices ensure product safety when loading or during inspections. The temperature of transport would also determine the potential for growth of pathogens. Thus, refrigeration temperatures are used to transport many produce items. The cold temperature helps to preserve product quality as well as safety.

1.3.5 Fresh-Cut Fruit and Vegetables: Potential Hazards

The fresh-cut fruit and vegetable industry in the United States grew from supplying quick-serve restaurant chains to providing consumer-size convenience products. From the 1980s to the 2000s, bagged salads and other convenience items experienced tremendous growth in demand. Sales of bagged salads topped $3 billion in 2004, while whole peeled carrots reached about $1 billion (Gorny, 2005).

Fresh-cut processors have worked with growers, retailers, and food service operations to ensure raw material and finished product are handled safely. When fresh produce is washed, cut, and sliced, the natural defense mechanisms on the plant material are removed. The high level of handling increases the potential for product to be contaminated by microorganisms in the environment. Because there is no kill step in fresh-cut processing, using HACCP is imperative in maintaining food safety standards with preventive programs (Nguyen-the and Carlin, 1994, 2000). Growers implement Good Agricultural Practices (GAPs) reducing risks during growing and harvesting (FDA, 1998a). Retailers and food service operations implement the principles of HACCP to manage food safety in their operations. In the United States, the International Fresh Cut Produce Association (IFPA) published Food Safety Guidelines for fresh-cut food processors. Guidance documents produced include a model HACCP plan, best practice guidelines for activities,
a model food allergen plan, and a Sanitary Equipment Buying Guide and Development Checklist. The IFPA has also developed a GAP program in conjunction with the Western Growers’ Association. The industry is thus equipped with proactive guidance to produce safe food.

1.3.6 Retail and Food Service Operations

The primary cause of foodborne illness in the United States is thought to be the mishandling of food during preparation in food service operations or in the home (Gorny, 2005). Statistics collected by the Center for Disease Control and Prevention (CDC) provide a strong link between foodborne illness outbreaks and the end users in restaurants and retail (CDC, 2004). Consumers could be a source of fresh produce contamination in retail outlets. Consumers touch fruit and vegetables as they make a decision on whether to purchase product. If a person’s hands are contaminated because of improper hygiene, this product could be affected. The consumer may also place bare fruits and vegetables into shopping carts, which are generally unwashed. Cross-contamination by microorganisms present in the shopping cart onto fresh produce items could present a food safety hazard, especially if the cart was used to transport meat, fish, or poultry. The final step of bagging produce items could present a food safety hazard if fruits and vegetables are placed in the same bag as raw meat or fish.

When the consumer places grocery bags in the car, vehicle temperature and time to cooling determine the potential for present pathogens to multiply. Linton (2003) describes a “temperature danger zone” of 5–60°C for food in general. A rule of thumb in the industry is that it takes four hours in the temperature danger zone for pathogens to multiply enough to cause illness. For this reason, hot food should be stored at temperatures over 60°C and cold foods at less than 5°C for optimum safety (Linton, 2003).

Retail operations and restaurants should take a proactive role in carrying out a risk assessment of their operations to understand the different types of hazards. When these potential problems are identified using the principles of HACCP, they may be controlled. Salads and juices are sometimes prepared in the fresh produce section of a retail operation. Workers should be trained in good food-handling practices to ensure food quality and safety are maintained:

1. Ready-to-eat foods should be kept at safe temperatures.
2. Food contact surfaces in food-preparation areas should be cleaned and sanitized regularly.
3. Display counters and shelves should be cleaned regularly to prevent cross-contamination.
4. Water used to wash produce should be potable, because poor-quality water is a major source of contamination.
5. Color-coded chopping boards should be used to distinguish boards for cutting produce from those used for cutting meat.
6. Employees bagging product at the cashier’s desk should be trained to avoid cross-contamination by placing raw meat in separate bags from fresh produce.

7. Regular hand washing should be enforced to prevent product contamination.

All employees in a retail operation should thus have a basic knowledge of food safety and their responsibility of protecting the public.

Outreach and education of the consumer would be the most effective means of explaining the dangers of mishandling food to the ultimate customers. Retailers may also assume the role of educating the public so the food-safety message reaches into people’s homes. Brochures, videos, and posters at display counters have been used effectively for consumer education in retail operations. Modern technology and a bit of creativity on the part of retailers could go even further to enlighten the public and promote safe handling of food.

Restaurant chains represent one important point in the handling of fresh fruits and vegetables before consumption. Food-service operations have been linked to several foodborne outbreaks involving fresh produce (CDC, 1999; CNN, 1996, 2003). Adequate training of food-service employees and implementation of a HACCP program to control food-safety in kitchens and food-display counters are the best ways to control food handling.

The “Serve Safe” program developed by the International Food Safety Council of the National Restaurant Association Educational Foundation has become the industry standard in food safety training. Serve Safe is accepted in almost all U.S. jurisdictions that require employees’ certification. The Serve Safe program provides accurate, up-to-date information for all levels of employees on all aspects of handling food, from receiving and storing to preparing and serving. The International Food Safety Council promotes food-safety education to the restaurant and food service industry, and also conveys the industry’s food-safety commitment to the public. The Serve Safe program has introduced a number of control measures for food-service operations similar to those mentioned above for retailers handling minimally processed product. In the United States, food service operations may also be subject to food-safety inspections, depending on the laws in each State. Only a very strict food-safety program in food-service operations would reduce the risk of pathogen contamination and illness to the ultimate consumer. The topic of U.S. retailer programs reducing food-safety risks in stores and educating the public will be presented in Chapter 8.

1.3.7 Consumer Handling of Fruits and Vegetables

Fruit and vegetables, besides being perishable items, could be the source of mishandling by consumers, eventually leading to foodborne illness. Consumers sometimes mishandle produce by cross-contamination with meat items being placed in the same bag or cart. Temperature abuse in a hot car would promote the growth of microorganisms, if present. In the home, food-safety practices such as hand
washing before handling fresh produce, or after handling meat, may not be observed. Most consumers store produce in the refrigerator; however, some items are stored at room temperature (Li-Cohen and Bruhn, 2002). Room-temperature storage is good for tomatoes, bananas, and unripe climacteric fruits. However, refrigeration extends the freshness and slows bacterial growth if a produce item contains harmful microorganisms. The home refrigerator may also harbor harmful organisms if it is not cleaned routinely. Meat drippings on shelves could cross-contaminate fresh produce placed on the same shelves. Consumers do not generally have a cleaning schedule for refrigerators, but this is a critical point in home hygiene in the kitchen. Refrigerator surfaces should be cleaned and sanitized to remove potential pathogens every two weeks, or more often, depending on contamination.

Another reservoir for pathogenic microorganisms is the kitchen sink. Consumers may place fresh produce items in the sink without washing or sanitizing the area. This causes cross-contamination from items previously placed in the sink. Sinks should be cleaned and sanitized before being used to wash fresh fruits and vegetables. In addition, mixing of utensils would invite cross-contamination, leading to foodborne illness. Consumers may not always wash fruits and vegetables, but even the simplest washing with running water is sufficient to cause one log$_{10}$ CFU/g reduction in microbes. Fresh-cut fruit and vegetables should always be stored in refrigeration, first to extend shelf life, and then to reduce the potential growth of pathogens, which are usually mesophilic organisms. Chopping boards carry microorganisms in the form of biofilms if they are not cleaned and sanitized thoroughly. Consumers should implement good cleaning programs when using chopping boards for fresh produce, and preferably use different utensils than those used for meat.

Consumer attitudes to handling of fresh produce and statistical data collected in surveys of consumer behavior will be presented in Chapter 9.

1.4 MITIGATION MEASURES

1.4.1 Improvements in Produce Handling and Research Efforts

Scientists at the Agricultural Research Service, USDA, proposed research programs in 1999 to investigate new technologies for decontaminating fresh produce containing human pathogens. The presence and survival of human pathogens in unpasteurized juices, sprouts, melons, lettuce, and berries is known. These commodities have been implicated in a number of foodborne illness outbreaks. Typical methods of washing and sanitizing produce are not effective in removing pathogens, and increasing the knowledge of sources of microbial contamination requires more research. Thus, scientists have tried to identify sources of human pathogen contamination and develop interventions to prevent contamination and remove or inactivate pathogens on fresh and minimally processed produce (Beuchat, 1998; Jaquett et al.,
These studies provide a foundation for the development of treatments to assure the microbiological safety of fresh produce.

Sapers et al. 2000 showed that washing with hypochlorite or commercial surfactant formulations, as a means of decontaminating apples inoculated with \textit{E. coli}, had limited success with only 1 to 2-logs (90–99 percent) reduction. However, experimental washing with hydrogen peroxide resulted in a 3-log (99.9 percent) reduction. Annous et al. (2001) demonstrated the inability of brush washing to decontaminate apples in field tests. It was thought that bacteria in inaccessible sites, growth of bacteria in skin punctures, and possible infiltration of bacteria into calyx and core tissues prevented their destruction.

In work with apples, mature and immature fruit from various locations were examined for evidence of internal or external bacterial contamination. A decay-causing fungus, \textit{Glomerella cingulata}, permitted growth of \textit{E. coli} O157:H7 in inoculated apples, probably because of a decrease in acidity that resulted from fungal growth. This clearly demonstrates the potential risk of using decayed apples for production of unpasteurized cider (Riordan et al., 2000). Sapers et al. (2001) researched the microbiology of fresh and fresh-cut cantaloupe, providing knowledge about attachment and survival of bacteria, including surrogates of human pathogens on external melon surfaces. They studied the efficacy of washing treatments in decontaminating cantaloupe melons, and effective treatments for extending the shelf-life of fresh-cut cantaloupe. Cantaloupe melons were artificially contaminated with nonpathogenic \textit{E. coli} and \textit{Salmonella stanley}, a human pathogen, and survival of these bacteria on melon rind during washing and their transfer to the melon flesh during fresh-cut processing was measured. Researchers found that chlorine and hydrogen peroxide solutions became progressively less effective in reducing contaminant populations as the time between contamination and washing increased. Surviving bacteria were transferred to the melon flesh and growth occurred (Sapers et al., 2001).

Chlorine dioxide is one sanitizer approved by the U.S. Food and Drug Administration (FDA) and the Environmental Protection Agency (EPA). Chlorine dioxide is said to be as powerful as peroxyacetic acid and more economical. It has less of a negative impact on the environment than quaternary ammonium salts, chlorine, or bromine (Stier, 2005). Ozone and peroxyacetic acid have been introduced to decrease the microbial content of fresh-cut produce. Chlorine bleach and bromine create carcinogenic trihalomethanes that enter the environment through drains. Chlorine dioxide is also thought to destroy biofilms and prevent their formation. Chlorine continues to be the most widely used sanitizer in the produce industry in the United States; however, certain countries in the European Union have banned its use. Heat pasteurization is one innovation receiving a great deal of attention in disinfecting fresh-cut apples and melons (Gorny, 2005). The outside of the fruit is pasteurized before cutting, thus reducing the entry of surface microorganisms to the flesh.

In fresh-cut processing operations, ATP bioluminescence is used to monitor food contact surface contamination. It is a rapid means of informing sanitation crews if
bacteria and organic material remain on food contact surfaces. This method of testing is, however, very expensive and finds application mainly in large processing operations.

**US Food Safety Programs: GAP, GMP, and HACCP.** Use of GAP, GMP, and HACCP is voluntary in the fresh produce sector. However, retailers have demanded that their suppliers implement structured food-safety programs under various schemes and these practices are now subject to auditing by a third party.

Good Agricultural Practices (GAPs) describe preventive measures implemented in farming operations to reduce product contamination. The U.S. government in 1998 introduced a “Guide to Minimize the Microbial Contamination of Fresh Fruit and Vegetables”. This Guide was used in the United States, as the basis for developing GAPs (FDA, 1998a). The major risk factors identified as needing control included water, manure, worker health and hygiene, sanitary facilities, pest control, and traceback. GAPs provide guidance for food-safety practices in the field. Implementing GAPs provides some assurance to the retailer that product is safe from the farmer’s gate. A small number of foodborne illnesses have been associated with contamination at the farm through an ill harvester, or use of unsanitary water.

Current GMPs (FDA, 2003) were made law in U.S. food-processing and handling facilities and this code has been reviewed. The code provides guidance on the safe handling of product in buildings used for food production. In the fresh produce sector, packhouses should follow guidance set out in cGMPs in order to put out wholesome food product.

The principles of HACCP, a system developed by the NASA space program in the 1950s, are now used as the basis for risk assessment and initiating food-safety measures throughout the industry (FDA, 2001). Although most fresh produce farming and packing operations do not have critical control points, the HACCP program forces operations to go through each area in a packhouse, conducting a risk assessment. The assessment may also indicate where GMPs are failing and help in improving GMPs. The use of GAPs, GMPs, and HACCP in the fresh fruit and vegetable industry provide the basic framework for safe products for the consumer.

### 1.4.2 Improvements in Distribution and Retail

To aid the integration of the supply chain from the source to the end consumer, automated systems are being developed. These data-based systems would provide complete and constant visibility of product, package, purchasing, and distribution of food. Automated warehouse management systems using robotics could increase accuracy of the picking and assembling of pallets for dispatch. With laws restricting the weight of product lifted at food plants, automated systems could also aid manufacturers in compliance with labor laws. As customer demands for fresh
product increases, smaller, more frequent deliveries will be required. Automated warehouse management systems would again improve accuracy of product rotation and picking for small deliveries. Automated systems would improve inventory control and real-time tracking of products that pass through a warehouse.

The advent of barcoding has revolutionized the way product movement is managed. A unique barcode is prepared for product harvested on the farm. This barcode stores information on the grower, farm lot number, day harvested, and crop harvested. A barcode placed on a bin of fruit after harvest could then be scanned at the packhouse at intake. This code stays with the bin until it is repacked into consumer size items. If product were stored before repackaging, the warehouse management system would assist in stock rotation based on information received from the barcode. When product is repacked into consumer size packages, a new barcode is placed on the product to assist in tracing finished product back to the field in case of an emergency.

The Uniform Code Council (UCC) takes a global leadership role in establishing and promoting multi-industry standards for product identification and related electronic communication. The purpose of UCC/EAN-128 is to establish a standard way of labeling a package with more information than just a product code. It provides supplemental information such as batch number and “use before” dates. The symbology for this is the UCC/EAN-128, which can be scanned to capture automatically the details related to the location (EDI, 2005). International standards in barcoding include the use of a Global Location Number or GLN. This is a number that identifies any legal, functional, or physical location within a business or organizational entity such as

1. Legal entities – whole companies, subsidiaries, or divisions such as supplier, customer, bank, forwarder;
2. Functional entities – a specific department within a legal entity, such as the accounting department;
3. Physical entities – a particular room in a building, such as a warehouse or warehouse gate, delivery point, or transmission point.

Such GLNs are governed by strict rules to guarantee that each one is unique worldwide. They always have the following features:

1. They are numeric.
2. They have a fixed length of 13 digits, which must be processed in their entirety.
3. They end with a check digit.

The GLNs can be presented in barcode format and physically marked onto trade units to identify the parties involved in the transaction (buyer, supplier), for
example (1) transport units (consignor, consignee), (2) physical locations (place of delivery, place of departure).

X-ray technology is another method with great potential in identifying physical contamination in fresh fruits and vegetables. The widely used metal detectors are not able to detect wood chips, plastic, and other nonmetal contaminants. Thus, machine vision systems could help in eliminating foreign contaminants in food. The cost of purchasing equipment and adapting it to fresh-produce operations far exceeds the benefits from using this technology.

Although some in the produce industry are still grappling with the introduction of barcoding systems for traceability programs, other sectors in the food industry have moved on to the new technology of radio-frequency identification (RFID) systems, a technology that uses grain-sized computer chips to track items at a distance. Each tiny chip is connected to an antenna that picks up electromagnetic energy beamed at it from a reader device. When it picks up the energy, the chip sends back its unique identification number to the reader device, allowing the item to be remotely identified. “Spy chips,” as they are sometimes called, can beam back information anywhere from a few inches to 30 ft (~10 m) away. This RFID will be used in the future to trace product. Retailers such as Walmart have started demanding this technology for packaged goods. Within time, this technology could be used to assist in stock rotation and distribution of fresh produce.

Radio frequency identification is not necessarily better than barcodes. The two are different technologies and have different applications, which sometimes overlap. The big difference between the two is that barcodes are a line-of-sight technology. In other words, a scanner has to see the barcode to read it. This means that people usually have to orient the barcode towards a scanner for it to be read. Radio frequency identification, by contrast, does not require line of sight. RFID tags can be read as long as they are within range of a reader. All existing RFID systems use proprietary technology, but many of the benefits of tracking items come from tracking them as they move from one company to another and even one country to another. RFID readers could cost as much as $1000, making it too expensive for small companies. This technology is still cost-prohibitive, but many large companies are creating proprietary supply-chain information systems to manage product flow and traceability. Another challenge would be sending radio waves through high water content fresh produce items (Gorny, 2005).

1.4.3 Traceability for the Industry

Traceability is defined as the “ability to trace the history, application or location of that which is under consideration.” The Codex Alimentarius Commission of the Food and Agriculture Organization defines traceback is the ability to track product from the consumer point of purchase back to the grower (Calvin, 2003). The objectives of a good traceability system should be to improve supply management and aid traceback of food-safety and quality parameters. Some companies use their traceability programs as a marketing tool to differentiate them from competitors because of the benefits of the program. In most cases, a well-run traceability
program can generate revenue for a company because it improves efficiency at all levels. The source of a safety or quality problem can be isolated and managed using a detailed traceability program. Benefits of traceability also include the fact that unsafe products are not shipped, and the risk of bad publicity, lawsuits, and recalls is reduced. A detailed tracing system would speed corrective actions when food-safety and quality problems are identified. Many large restaurant chains and retailers now expect their suppliers to create traceability systems. These systems are verified through third-party audits of overall food-safety systems. If a product recall or foodborne illness occurs, an investigation is well controlled if a company has a means of retrieving information. This would help in identifying a problem in the production system and point to immediate corrective actions.

Under the FDA Recording and Reporting Rule of the Bioterrorism Act 2002, food companies must provide the FDA with source data, including immediate previous source (IPS) and immediate subsequent recipient (ISR) for every component of a food item (FDA, 2002). U.S. and international food processors, transportation, and distribution companies must keep records if food or biological products are imported or exported from the United States. Companies have developed innovative software databases in information systems with the ability to store detailed crop history and distribution data. Guidelines have to be set so that meaningful data can be stored and retrieved when needed. Systems usually include information on the shipper, date harvested, field, and picker.

The basic requirements of information databases are

1. To quickly isolate affected product in the event of a recall;
2. To track spray intervals to harvest and pesticide application records, if pesticide use is a concern;
3. To keep historical data on fields where crops were grown.

The U.S. Government has developed systems to monitor the incidence of foodborne illness. FoodNet (www.cdc.gov/foodnet/) and PulseNet (http://www.cdc.gov/pulsenet/) are surveillance systems that increase the capability of the entire food supply chain to respond to food-safety problems before more consumers are affected. FoodNet – Foodborne Diseases Active Surveillance Network (FoodNet) – is a collaborative project of the CDC, ten Emerging Infections Program (EIP) sites, and the U.S. Department of Agriculture. PulseNet is a national network of public health and food regulatory agency laboratories coordinated by the Centers for Disease Control and Prevention (CDC). The network consists of state health departments, local health departments, and federal agencies (CDC, USDA/FSIS, and FDA). PulseNet participants perform standardized molecular subtyping (or “fingerprinting”) of foodborne disease-causing bacteria by pulsed-field gel electrophoresis (PFGE), which can be used to distinguish strains of organisms of public health significance.

Scientists can trace fresh produce microbial contaminants using genetic data. The global food-safety testing market is expected to reach as much as $415.6 million by
the year 2009 (Food Safety Magazine, 2005). The increase in pathogen test sales continues to rise because of many factors, including

1. Consumer demand for safe food;
2. Evolution of bacteria and emergence of new strains;
3. Increased government regulation.

Food testing globally focuses on pathogens, pesticide residues, genetically modified organisms (GMOs), and other contaminants. In the United States, pathogen testing far exceeds pesticide testing in foods. This is different in the European Union, where testing focuses on pesticide residues. The European Union has also required increased documentation of GMO-containing foods and testing for identity preservation may increase in the future.

1.4.4 Effectiveness of Auditing

Customers are reassured when information supplied by companies is verified by third-party certification. Different forms of auditing include self-audits, second-party audits, and third-party audits. Self-audits are used by companies to monitor the efficiencies of in-house programs: food safety, GMP, HACCP, and so on. Self-audits may be used as a tool to monitor execution of QA and QC programs. One setback would be the familiarity of the auditor with the operation and his inability to view errors in the system objectively. A company verifying practices of its suppliers conducts second-party audits. Some bias is removed, because the company would want the best-quality product as raw material and packaging from vendors. Third-party audits are conducted by neutral auditing firms that carry out inspections on behalf of a retailer or other party of interest. The auditing firm does not usually have a stake in the business and so the assessment is felt to be unbiased. In order to be effective, third-party auditors should be knowledgeable about the business they are auditing and well versed in the standard against which they are auditing.

Different auditing and certification protocols exist in different parts of the world. Each protocol may be applied in a specific area of the food chain, but there is no one correct auditing scheme. Nations have not yet united all schemes under one accreditation body. Good Agricultural Practices (GAPs) refer to food-safety guidelines for field operations and each auditing firm has its own verification system for monitoring GAPs. Another scheme for farm safety, EurepGAP, has been developed in Europe. This protocol provides many allowances for environmental and social issues in the growing operation. European retailers who helped develop the EurepGAP auditing scheme ask growers and shippers to subscribe to this auditing program.

Good Manufacturing Practices (GMPs) have been clearly defined by the U.S. FDA for food processing operations (FDA, 2003). Different auditing firms in the United States would interpret GMP guidelines and audit packhouses and processing
plants based on their own checklist. The U.K. Food Safety Act 1990 states that all persons involved in supplying food have an obligation to take all reasonable precautions and exercise all due diligence in avoiding failure when presenting food products to the consumer. Retailers are thus obligated to verify technical performance at food-production sites. In 2003, the British Retail Consortium (BRC) proposed a Food Technical Standard applying to enclosed areas for food production. The standard has been updated with version 4, the BRC Global Standard – Food, in June 2005. This standard for food establishments is seen to be a major international standard specifying safety, quality, and operational criteria within a food manufacturing operation. Accredited auditing bodies inspect food establishments against this standard. Schemes such as the BRC’s Global Food Standard provide training for auditors based on the set standard. Training ensures uniformity in auditing.

Another example of a certification protocol is the International Organization for Standardization’s ISO 9000 series, or “EN 29000,” in Europe. In 1987, ISO published a series of five international standards (ISO 9000, 9001, 9002, 9003, and 9004), developed by ISO Technical Committee (TC) 176 on quality systems. This series, together with the terminology and definitions contained in ISO Standard 8402, provides guidance on the selection of an appropriate quality management program (system) for supplier operations. Conformance to ISO 9000 standards is required in purchasing specifications by some companies. The ISO 9000 Standard Series was adopted in the United States as the ANSI/American Society for Quality Control (ANSI/ASQC Q 9000 series). In Europe, the series was adopted by the European Committee for Standardization (CEN) and the European Committee for Electrotechnical Standardization (CENELEC) as the European Norm (EN) 29000 Series. Many countries have national standards that are identical or equivalent to the ISO 9000 Standard Series (Breitenberg, 1992).

Growers use results of third-party audits of GAPs as a tool to demonstrate that effective due diligence programs are in place. When the FDA introduced GAPs for the produce industry, auditing firms used these guidelines to develop extensive auditing programs for the fruit and vegetable industry. Retailers rely on auditing firms to provide them with the assurance they need from their suppliers. However, fruit and vegetable growers in the United States have the following concerns:

1. There is no government regulation of third-party auditing companies.
2. Food auditors from the food-processing industry attempt to apply the same standards of auditing in open fields.
3. Cost of auditing fees is seldom supported by an increase in revenue for growers.
4. Different retailers may demand different auditing programs, because there is no industry standard.

A major retailer, Tesco, has developed the Tesco Nature’s Choice standard for growing and packing operations. Walmart has developed the Walmart Global
Procurement Group Audits. Safe Quality Food (SQF 1000), a scheme owned by the U.S. Food Marketing Institute, verifies food safety as well as quality of product. Retailer auditing programs are not necessarily similar and may increase costs for those growers that supply different stores. Microbial food safety is the focus of United States based produce industry audits. However, there are insufficient data to establish actual risks of microbial contamination in the industry. Thus, auditing is based on many assumptions of risk. Even companies that passed audits have been associated with foodborne outbreaks (Calvin, 2003). This shows that food-safety programs allow for a minimization of risk, but not complete elimination of microbial contamination.

The consolidation and globalization of the retail industry has brought a new dimension to the auditing process. It is hoped that the market will consolidate its basic food safety requirements. The U.S. culture of regulatory control of the food industry is different to the European Union, where a culture of private certification exists. In addition, niche markets may make higher demands of suppliers.

Auditing schemes could be made more effective by the following steps:

1. Developing data to assist in objectivity of decision-making in auditing;
2. Testing and evaluating management tools to add objectivity to audits;
3. Introducing controls on accreditation schemes for auditors in all countries;
4. Harmonizing international auditing schemes so they cover major quality and food-safety concerns;
5. Developing product-specific and region-specific auditing schemes;
6. Introducing an international accreditation body using set standards to verify programs of all auditing bodies, thus making the auditing process uniform.

The Global Food Safety Initiative (GFSI) was created in May 2000 at the initiative of a group of major retailers, including METRO AG, Rewe, Edeka, and Globus. The GFSI is a working group within the CIES (The Food Business Forum), an international network of companies in food retailing and food production. In total, 250 major food retail companies are represented in CIES. GFSI is a separate legal entity governed by an Advisory Group. The mission of GFSI is to strengthen consumer confidence in the food bought in retail outlets. GFSI is to develop product-related standards for food safety that cover all links of the food chain. It wants all suppliers to be audited and certified according to a uniform international standard. This will be achieved by implementing and maintaining a scheme to benchmark food-safety standards (for private label products) as well as farm assurance standards. GFSI will facilitate mutual recognition between standard owners and ensure worldwide integrity in the quality and the accreditation of food safety auditors (CIES, 2005). EurepGAP is also leading discussions to harmonize farm auditing schemes worldwide.
1.4.5 Educating the Public

The retail industry drives the introduction of GHPs in the food industry. As the last point of contact in the fresh-produce chain, retailers could play a proactive role in educating the public on safe food-handling practices.

Programs retailers may use to educate the public include the following:

1. Use of membership cards and frequent shopper cards to store data on buying patterns of regular customers;
2. Tailor-made food safety information to send to customers;
3. Posting signs on the sides or handles of shopping carts to deliver food-safety information to the customer before they enter the store;
4. Posting point-of-sale signs, wall hangings, and floor markers;
5. Distributing fliers with information in shopping bags to keep the customer informed and aware of food-safety issues concerning the item purchased;
6. Posting food-safety information on retailer websites;
7. Sponsoring radio/TV and other media programs promoting food safety;
8. Using videos in store to impart knowledge of safe food-handling practices;
9. Using demonstration stations in the store to sample new food items while incorporating food-safety education.

In the United States, Federal Governmental agencies (the FDA, USDA, and CDC) are responsible for setting and monitoring food-safety standards, as well as communicating key food-safety knowledge to consumers. Local government agencies have been busy educating and informing consumers in the areas of food safety. “Fight Bac!” is one government program that was a success and can serve as a model for conveying food-safety knowledge to the consumer (www.fightbac.org). Educational material for consumers must be presented in a convenient way. According to Li-Cohen and Bruhn (2002), consumers who were interested in receiving information found brochures in supermarkets informative. Consumers also preferred it if information was presented in easy-to-follow picture form, instead of wordy material. Information should also be targeted toward children as part of school studies and with special activities. For example, safe food handling could be a required component of any social studies curriculum. It is important to channel food-safety education to school-aged children, the consumers of the future. Educating children in safe food-handling practices would perhaps reduce foodborne illnesses for future consumers.

In 1994, the National Restaurant Association Educational Foundation’s (NRAEF) International Food Safety Council created National Food Safety Education Month® as an annual campaign to heighten awareness about the importance of food-safety education. Each year a new theme and training activities are created for the restaurant and food-service industry to reinforce proper food-safety practices and procedures. Training material is accessible on the NRAEF website.
In addition, promotional materials are available to make it easier to spread the word about the importance of food-safety education.

### 1.4.6 U.S. Government Intervention

In the United States, Federal Agencies with roles in food-safety include the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA). These agencies monitor imports and have, in the past, surveyed production in foreign countries. The FDA oversees all import inspections, testing for pesticide residues or microbial contamination.

In 1997, President Clinton introduced the U.S. Food Safety Initiative to monitor the safety of all food in the United States. Under this program in 1998, the FDA produced the “Guide to Minimize Microbial Contamination of Food” (FDA, 1998a). This guide was intended to assist domestic and foreign growers, packers, and shippers of fresh produce by increasing awareness of potential hazards and providing suggestions to minimize these hazards. The basic principle in creating this guide was that prevention of microbial contamination was more effective than relying on corrective measures after contamination had occurred. The “Guide” provided broad-based voluntary measures and identified Water, Manure and Municipal Biosolids, Worker Health and Hygiene, Field Sanitation, Packing Facilities, Transportation, and Traceback, as risk factors for product contamination.

In March 1999, the FDA initiated a 1000-sample survey focused on high-volume imported fresh produce. Broccoli, cantaloupe, celery, cilantro, culantro, loose-leaf lettuce, parsley, scallions (green onions), strawberries, and tomatoes were collected and analyzed for *Salmonella* and *E. coli* O157:H7. All commodities except for cilantro, culantro, lettuce, and strawberries were analyzed for *Shigella*. Twenty-one countries were represented in the collection and sampling of fresh produce. Of 1003 samples collected, 4 percent were contaminated with *Shigella*, *Salmonella*, and/or *E. coli* O157:H7. Of the 44 contaminated samples, 35 (80 percent) were contaminated with *Salmonella*, 9 (20 percent) were contaminated with *Shigella*, and none was contaminated with *E. coli* O157:H7 (FDA/CFSAN, 2001c).

Because of the presence of pathogens in samples, 21 companies were placed on detention without physical examination (DWPE). Seven companies were placed on DWPE because *Shigella* was present in one composite, whereas 14 firms were placed on DWPE because of *Salmonella* in two composite samples. Another company was placed on DWPE for the presence of both *Shigella* and *Salmonella*. The FDA decided to remove the product, shipper, grower, or importer from DWPE only if evidence showed unsanitary conditions had been resolved.

In March 2000, the FDA initiated a 1000-sample survey focused on high-volume domestic fresh produce (the Domestic Produce 1000 Sample Survey, FDA/CFSAN, 2003). Cantaloupe, celery, cilantro, loose-leaf lettuce, parsley, scallions (green onions), strawberries, and tomatoes were collected and analyzed for *Salmonella* and *E. coli* O157:H7. In addition, cantaloupe, celery, parsley, scallions, and

(www.foodsafety.gov/~fsg/september.html)
tomatoes were analyzed for *Shigella*. This survey was the domestic complement to the FY 1999 Imported Produce Survey. Of 1028 domestic samples that were collected and analyzed, 99 percent were not contaminated with *Shigella*, *Salmonella*, or *E. coli* O157:H7. Eleven samples (1 percent of the total number sampled) were contaminated. Of the 11 contaminated samples, six (55 percent) were contaminated with *Salmonella* and five (45 percent) were contaminated with *Shigella*. For regulatory follow-up, domestic samples that were found to contain pathogens were reported to the collecting district and the Center for Food Safety and Applied Nutrition’s (CFSAN) Case Processing Contact. The domestic produce was either reconditioned or destroyed. Firms with contaminated produce were encouraged to conduct voluntary recalls. The FDA conducted follow-up investigations at three farms to determine potential sources of contamination.

In 2001, Congress provided the U.S. Department of Agriculture (USDA) Agricultural Marketing Service (AMS) with $6.235 million to implement a Microbiological Data Program (MDP) (USDA/AMS, 2003). Congress has followed this with appropriations of $6 million annually to continue the program. The aim of this program was to collect data on the incidence and identification of targeted foodborne pathogens and indicator organisms on fresh fruits and vegetables in the United States. The AMS formed a partnership with ten States, and in 2002 the MDP program tested five commodities: cantaloupe, celery, leaf lettuce, romaine lettuce, and tomatoes for *E. coli* and *Salmonella* sp. because of their public health significance. Of the 10,317 samples screened, MDP identified only 0.62 percent with virulence factors and three *Salmonella* spp. isolates from domestic leaf lettuce (0.03 percent of overall rate). The exercise, though not conclusive, showed new trends in fresh produce contamination. No significant differences were found in contamination rates between imported and domestic produce.

The FDA, in October 2004, developed the “Produce Safety Action Plan” to further minimize foodborne illness associated with the consumption of fresh produce (FDA, 2004). The plan was aimed at minimizing microbial food-safety hazards (bacteria, viruses, and parasites) in products from the United States and abroad. The Action Plan focused on all steps in the food chain from the farm to the home. Specific areas included farm production, packing, processing, transportation, distribution, and preparation of minimally processed product. The major objective of the plan was to reduce the number of illnesses per outbreak associated with fresh produce.

Forty-eight percent of CFSAN’s accomplishments in 2004 focused on a concern for food security and safety (Carrington and Cianci, 2005). The Bioterrorism Act of 2002 was signed into law on June 12, 2002. In 2004, two segments of this law were implemented – Administrative Detention and Prior Notice. Final rules for Food Facility Registration, Prior Notice of Imported Foods, and Record Keeping were published subsequently. When negotiating access to other markets with different standards, the United States uses the rules set out by the Agreement on the Application of Sanitary and Phytosanitary (SAPS) Measures, established by the World Trade Organization in 1995.

The FDA continues to review food regulations such as cGMPs to ensure they are up to date. In 2001, the FDA approved the Final Rule, making HACCP mandatory
for all juice processing operations. A critical control point (CCP) of the pasteurization step was considered the most effective means of destroying potential pathogens in juice (FDA, 2001).

1.4.7 Use of Surrogates and Indicators in Food Safety Research

Researchers have used surrogates and indicator microorganisms as tools in assessing fresh fruit and vegetable safety and the effectiveness of microbial control measures. FDA/CFSAN (2001b) defines an indicator organism as “a microorganism or group of microorganisms that indicate a food has been exposed to conditions posing an increased risk that food may be contaminated with a pathogen or held under conditions conducive for pathogen growth.” Indicator analyses are sometimes used to determine the effectiveness of sanitation programs. An indicator could be a specific microorganism, a metabolite, fragment of DNA, or other substance. For a detailed review of indicators, the reader is referred to Ray (1989), Mossel et al. (1995), Jay (1996, 2000), Smoot and Pierson (1997), and Buchanan (2000). The indicator should be present in the food when the target pathogen is present, should have similar growth patterns as the target, and be easy to detect and quantify.

Surrogate organisms are a unique type of indicator. They mimic growth and survival patterns of a pathogen and can help in studying what occurs with a pathogen during handling and storage. Surrogates are used to study the effects and responses to specific processing treatments. In the fresh fruit and vegetable industry, surrogates could be used to determine the effectiveness of a produce wash. They are usually prepared in a laboratory and introduced onto the produce item. They may also be microorganisms occurring naturally on the produce item (FDA/CFSAN, 2001b). Indicators are naturally occurring, whereas surrogates are introduced artificially on the food item for the study. Surrogates are frequently used for research as opposed to pathogens, because scientists need to prevent the release of harmful organisms in a production environment or, in the case of fresh produce, into a field. However, isolated pilot facilities have used actual pathogens for controlled research.

Mitigation measures in the fresh produce chain are mostly based on risk assessment and making an educated guess as to what measures would reduce the risk. Indicators and surrogates could be used to assure safety for individual produce items in all stages of the fresh produce chain: growing, harvesting, processing, handling, storage, distribution, and retail. These microorganisms may be used to determine the effectiveness of a water treatment or composting on pathogen reduction. If an indicator is in low concentration or not present, this could mean a treatment would be effective in reducing growth of the target organism. It is difficult to select the right target organisms, as well as an indicator organism that would relate to the target (Busta et al., 2003).

A surrogate should have the following main characteristics (FDA/CFSAN, 2001b):

1. It should be a nonpathogenic strain of the target organism.
2. It should demonstrate similar behavior as the target organisms in the environment studied.
3. It should be easy to prepare and stable.
4. It should exhibit enumeration, sensitivity, and inexpensive detection means.
5. It should attach to the produce surface at a similar rate as the target organism.
6. It should exhibit genetic stability to allow the test to be reproduced independently.

The use of surrogate organisms started in the low-acid canning industry. The thermophilic organism *Bacillus stearothermophilus* was used as a surrogate to establish processing conditions to destroy *Clostridium botulinum* spores (FDA/CFSAN, 2001b). Gram-positive and gram-negative bacteria, viruses, and protozoan cysts are pathogens associated with produce and foodborne outbreaks. Strains of *Listeria innocua* have served as nonpathogenic surrogates of the pathogen *Listeria monocytogenes* (Corte et al., 2004).

Worobo (1999) used a nonpathogenic surrogate microorganism, *E. coli* ATCC 25922, with the same UV sensitivity/resistance as three pathogenic strains of *E. coli* O157:H7, to evaluate effectiveness of UV irradiation to sanitize apple cider. Numerous strains of microorganisms were tested and differences in the response to ultraviolet light were observed. Because ATCC 25922 showed almost identical UV sensitivity to *E. coli* O157:H7, it was used as the surrogate microorganism to test additional production units. This surrogate was used to validate each *CiderSure* unit (a measure of UV irradiation) to ensure its compliance with the regulated 5-log reduction of microorganisms for juice pasteurization.

Use of indicators and surrogates can be the most scientific means of generating data to validate the effectiveness of microbial control measures. Additional research is needed to identify specific surrogates and indicators for ready-to-eat and fresh-cut produce, thus helping to validate decontamination steps in the process. It is unknown if pathogens would develop increased resistance as a stress response when subjected to intervention steps. In addition, the country of origin and packing environment may induce a stress response (FDA/CFSAN, 2001b). Protocols have to be developed to accurately measure and retrieve indicator microorganisms after a stress is introduced. For an extensive list of research needs in the use of indicators and surrogates, the reader is referred to FDA/CFSAN (2001c).

Scientists raise concerns that researchers are not using established or comparative studies to validate their surrogates or indicator strains with the appropriate pathogen. The number of published works on attenuated pathogens has increased in several laboratories. However, researchers presume that elimination of virulence traits or entire plasmids has no impact on stress tolerance, phenotypes, competitiveness, or environmental persistence. These concerns must be addressed in future research.

### 1.5 Challenges for the Global Fresh Produce Industry

#### 1.5.1 Trends in Consumption and Globalization of the Industry

All countries share responsibility for food safety with the increase in international food trade. Consumers now benefit from worldwide trade with year-round supplies,
good quality, lower prices, and a wide variety of food (Buzby and Unnevehr, 2003). Food safety standards may sometimes present technical barriers to trade, but improvements in standards are likely to extend worldwide with the spread of private and governmental control. In the past, foodborne outbreaks were localized, but now, with increase in international trade, low-level contamination could possibly spread to many regions and even cross borders (Tauxe, 1997). Trade volumes are increasing for fresh, minimally processed, or high-value food, with an increase in imports from developing countries needed to fill the gaps (Hooker and Caswell, 1999; Lin et al., 1999). No scientific evidence has shown imported fresh produce to pose any greater food safety threat than U.S. grown products. In addition, less developed countries are acquiring higher food-safety standards to assist in entering new markets. Both Government agencies and private retailers and importers are driving this effort to increase food-safety standards. The higher standards do not, however, give complete protection from disease or injury.

Branded products, if perceived to be safe, could improve a firm’s image and international competitiveness (Buzby and Unnevehr, 2003). Private retailers and importers are strongly motivated to prevent a food-safety crisis, because their companies may suffer from loss of reputation, plants closing for cleanup, reduced stock prices, lawsuits, or higher insurance premiums. A crisis could affect an entire industry, as seen in the outbreak associated with Guatemalan raspberries (Calvin et al., 2002). Large organizations are now promoting vertical integration, controlling commodities at two or more stages of production (Martinez and Reed, 1996; Caswell and Henson, 1997). Private companies have promoted the following:

1. Self-regulation;
2. Vertical interaction;
3. Third-party certification;
4. Use of HACCP principles in risk assessment;
5. Application of voluntary GAPs in growing operations.

Government regulation also plays an important role in addition to the private sector. Industrialized nations saw the development of new food-safety regulation in the 1990s with improvements in science and increased awareness of food-safety risks. Regulatory agencies in industrialized nations were seen to follow main trends, forming agencies to focus only on food safety. Risk analysis was used to design guidelines for the industry and a “farm-to-table” approach has been used to address food-safety hazards. Some government agencies have adopted a HACCP-based system for new regulation of microbial pathogens in food. Newly identified hazards have encouraged adoption of more stringent standards and market performance has improved through the government providing the industry with more food safety information (Buzby and Unnevehr, 2003).

Trade disputes over food safety may be persistent, but are manageable. Food safety challenges vary with each commodity. Concerns differ, depending on the perishability of the product, the nature of human health risks, the possible link of
the food-safety issue with productivity, and the extent of vertical coordination and cooperation among stakeholders.

In the United States, fresh produce growers and shippers form many trade networks to promote year-round sales of once seasonal items. Because of improvements in storage technology, transportation, and communication, fresh produce is obtained from many new areas. Tariffs on many agricultural products have been eliminated, for example, the Caribbean Basin Initiative and the Andean Trade Preference Act (Calvin, 2003). Nontraditional suppliers now have increased U.S. market share – for example, asparagus from Peru (increased from 10 percent in 1990 to 47 percent in 2001). Cantaloupe from Costa Rica and Guatemala increased from 17 percent in 1990 to 60 percent in 2001 of all cantaloupe imports (Calvin, 2003).

Consumers are more frequently eating at food-service establishments. Even food-production practices have changed, leading to a host of new food-safety risks for the industry to manage. A marked increase in cut, ready-to-eat fruit and vegetables increases the challenge of preparing safe food. Consumers are demanding convenience food items to suit the hectic pace of the life we now lead. Washing, cutting, and preparing noncooked vegetables increase the potential for product contamination. This could increase the potential for more foodborne outbreaks because food handling is increased. Introduction of mandatory HACCP in juice processing in the United States was one move of the government to control food safety in the sector (FDA, 2001). Catering operations are monitored by food inspectors, whereas fresh-cut processing operations are audited at the request of retailers and restaurant chains. Food-safety programs in fresh-cut operations, however, are voluntary and not under mandatory regulation by government bodies.

Food-safety disputes could arise in trade with the appearance of new hazards or increase in volumes from new sources. Rising standards or changing food-safety regulation in industrialized countries would create new challenges for trade from developing nations. Different countries would have unique ideas with respect to consumer risk preferences. Nonscience issues also play a role in regulatory decision-making and this would vary from one country to the next (Buzby and Unnevehr, 2003). Growth in demand and increased access to markets will continue to expand food trade. Improvements in food safety are essential to consumer welfare and both producers and consumers have a stake in seeing the industry make great strides in this area.

1.5.2 International Oversight: WHO, European Commission on Health and Consumer Protection Directorate, Codex Alimentarius

The Codex Alimentarius Committee on Food Hygiene developed two codes of hygienic practice for fruits and vegetables. One focuses on primary production and the other on precut, ready-to-eat fruits and vegetables. The code of “Hygienic Practices for Fresh Fruits and Vegetables” includes an Annex on “Ready-to-Eat Fresh Pre-cut Fruits and Vegetables” and on “Sprout Production”. The World Health Organization (WHO) was also active in developing guidance for the fruit
and vegetable industry with the preparation of the document WHO/FSF/FOS/98.2 on surface decontamination of fruits and vegetables eaten raw (Beuchat, 1998; WHO, 2002). The European Commission on Health and Consumer Protection Directorate called on a Scientific Committee on Food to develop a risk profile on the microbiological contamination of fruits and vegetables eaten raw. This Committee developed a paper indicating that the proportion of reported food-borne outbreaks associated with fruits and vegetables is low (European Union Commission, 2002).

EU production of fruits and vegetables in 1998 was estimated at 76 million tons. Spain and Italy were the main producing countries, with 20 million tons each per annum, followed by France and Greece. The European Union also imports more fruits and vegetables than other nations through internation partnerships, as well as importing tropical fruits into the region. Cumulative impacts of food-related health crises have shaken consumer confidence in the safety of food products. The European Union has approached this challenge by putting in place a comprehensive strategy to restore people’s belief in the safety of their food “from the farm to the fork.” The European Union adopted general principles of food safety in a Regulation called the General Food Law introduced in 2002: Regulation (EC) No. 178/2002. This Law revised EU food safety legislation, with emphasis on feed because feed contamination had been at the root of major food scares. Under this Law, it became compulsory from January 1, 2005, for food and feed businesses to guarantee that all foodstuffs, animal feed, and feed ingredients be traceable right through the food chain. The General Food Law was supplemented by targeted legislation on other food-safety issues, such as use of pesticides, food supplements, colorings, antibiotics, and hormones in food production. In addition, the Law outlined stringent procedures on release, marketing, labeling and traceability of crops and foodstuffs containing genetically modified organisms (GMOs). Updated rules on hygiene took effect on January 1, 2006, with the introduction of Regulation (EC) No. 852/2004 on the hygiene of foodstuffs as well as other specific rules.

The European Food Safety Authority (EFSA), headquartered in Parma, Italy, plays a central role in providing scientific data for food safety. The EFSA can cover all stages of food production and supply, from primary production to the safety of animal feed, right through to the supply of food to consumers. It can also look into the properties of nonfood and feed GMOs and nutrition issues.

The EFSA provides the European Commission with independent, scientific advice that is also made public to enable it to be fully open to scrutiny. It provides input when legislation is being drafted and advice when policymakers are dealing with a food scare.

The Commission enforces EU feed and food law, seeing that EU legislation has been incorporated into Member State law. The Commission also checks compliance through reports from Member States and other countries and through on-the-spot inspections in the EU and abroad. The Commission’s Food & Veterinary Office (FVO) based at Grange in Ireland conducts inspections. The FVO can check individual food production plants, but its main task is to check that EU governments and
those of other countries have the necessary machinery for verifying their own food producers.


1.6 SUMMARY

Increase in global trade and organic farming expose consumers to produce with limited information on microbial safety. For example, limited data exist on the use of microbes for biocontrol of pests. In addition, chemical decontaminants and their impact on microbial food safety is not well known. There are no clear trends in consumption of specific categories of whole fruits and vegetables. However, convenience food items like cut and ready-to-eat fresh fruit and vegetables are increasing. This increase in handling could also increase the potential for product contamination. Water quality is a major factor affecting product contamination in the farm, packhouse, processing facility, and in the home.

Sprouted seeds and fruit juices have been associated with foodborne outbreaks and special legislation provides extra control measures to protect these products. Good Agricultural Practices and Good Handling Practices are thought to be the basis for safe production of fruits and vegetables. The industry relies on proactive systems to reduce risks during production and handling, because decontamination steps have limited effects on safety. There are insufficient scientific data to quantify actual risks at each stage in the fresh produce chain, but with increased research, industry can gain insight into developing adequate preventive measures.

Foodborne illnesses associated with fresh produce are low compared to products of animal origin. Detailed traceability programs can improve the epidemiological investigation and identification of factors causing foodborne outbreaks. These investigations would then lead to the control of the causative agent. Because only a few developed nations have surveillance programs on foodborne pathogens in place, it is not easy to compare outbreaks among many countries. An international effort should take place to introduce surveillance systems in densely populated nations. In addition, scientists should collect data on the potential for organic farming methods to contaminate fresh fruit and vegetables.

Governments could play a role in creating national regulations that influence the safe production of fruits and vegetables. The globalization of the food supply requires a concerted effort from all stakeholders, with preventive measures in
place from farm to fork to protect the consumer. This publication focuses on the U.S. fresh produce industry and provides a summary of microbial hazards from production to consumption. Through identification of the hazards and review of mitigation measures, fresh produce suppliers can continue to learn and provide consumers everywhere with safe and healthy fresh fruit and vegetables.

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